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COMBUSTION METHOD AND BURNER HEAD, BURNER HAVING SUCH A BURNER HEAD, AND BOILER HAVING SUCH A BURNER HEAD

[0001] In the conventional oil burner, the heating oil is injected at high pressure into the incoming air flowing into the combustion chamber. The difference in speed between the air and the oil droplets favors evaporation of the oil and thus leads to a reduction in the size of the oil droplet, until finally the difference in speed between the air and the oil droplets has vanished. As the speed decreases, the evaporated liquid around the droplet forms a mixture of fuel vapor and air with an increasing proportion of fuel vapor. The flammability of the mixture increases during the combustion process. Because of the heat in the flame that already exists in the burner, this increasingly more readily flammable mixture ignites.

[0002] In yellow-flame burners, to prevent the flame from separating from the burner head, an underpressure zone is created, centrally or annularly around a central region, with a blocking disk. A lesser quantity of incoming air, set into rotation, is delivered to this underpressure zone. The fuel is also injected into this underpressure zone. In this flame core, it burns under conditions of oxygen deficiency. Secondary air is delivered in relatively large quantity centrally and/or through an annular slot around this underpressure zone and allows the combustion of all the delivered fuel in an elongated flame. Thanks to the central underpressure zone and the supply of fresh air enveloping it, the flame core and hence the entire flame is aspirated against the blocking disk. The flame therefore persists downstream of the blocking disk and does not separate from it.

[0003] In this combustion, however, a high flame temperature is reached. This high temperature on the one hand leads to carbonization of the fuel nozzle, which impairs the safety and reliability of operation, and on the other hand leads to favorable conditions for the combining of nitrogen from the air with oxygen from the air. In this kind of combustion, the result is an excessive concentration of nitrogen oxides (NOx). In this combustion, the flame is yellow. The yellow light is given off by glowing carbon, which is created by the decomposition of the fuel.

[0004] It has been discovered that the concentration of the resultant nitrogen oxides is

very strongly dependent on the combustion temperature. Each reduction of the temperature by 100°C reduces the NOx concentration to half the previous value. If it is possible to lower the combustion temperature by 300°C, the NOx concentration is accordingly then only about 1/8 that of combustion with a yellow flame.

[0005] Cooling the flame is attained by means of an excess of incoming air, a purposeful recirculation of exhaust gases, and/or a spatial separation of the evaporation zone and the mixing zone.

[0006] To reduce NOx values in the flue gas in the combustion of heating oil, so-called blue-flame burners have been developed. With the blue-flame burners, the combustion zone is separated from the evaporation and mixing zone as much as possible. In the process, the fuel in the incoming air or in a mixture of incoming air and combustion gas is evaporated and thereafter combusted. In burners that make a virtually stoichiometric combustion possible, recirculation of the exhaust gases must be provided for.

[0007] From European Patent Disclosure EP-A 0 321 809 (Brown Boveri AG), a method and a burner are known for the premix kind of combustion of liquid fuel in a burner. The burner has two complementary that put together make a hollow cone, and between which there are tangential air inlet slits. The hollow partial conical bodies have a conical inclination that increases in the flow direction. The cone axes of the partial conical bodies are spaced apart from one another, and between these cone axes there is a fuel nozzle, which injects a liquid fuel into the hollow cone at an angle that assures that the fuel does not wet the wall of the hollow cone. Through the tangential air inlet slits, air is delivery, which forms a jacket around the fuel fog and rotates around the fuel cone. In the region where the turbulence breaks up, that is, in the region of a central return-flow zone in the orifice region of the hollow cone, the fuel-air mixture reaches its optimal, homogeneous fuel concentration via the cross section of the turbulence. The ignition takes place at the tip of the return- flow zone.

[0008] With this burner, the least pollutant emissions values are achieved when the evaporation is concluded before the entry into the combustion zone. This is equally true for combustion with an air excess of 60%, and if this air excess is replaced with recirculated

exhaust gas. How the exhaust gases are recirculated cannot be learned from this reference. In designing the partial cone bodies in terms of their conical inclination and the width of the tangential air inlet slits, narrow limits must be adhered to, so that the desired flow pattern of the air with its return- flow zone in the region of the burner orifice for flame stabilization will be established.

[0009] According to European Patent Disclosure EP-A 0 491 079 (Asea Brown Boveri AG), one disadvantage of this burner is that in some cases, it cannot be used by atmospheric combustion installations. This reference therefore proposes a burner head that has minimal pollutant emissions and in which, by the shaping of the burner head and the guidance of the incoming air through the burner, stabilization of the flame is established at the end of a premixing zone in the center and/or on the outer periphery of the combustion chamber. Evidently, the flame stability of the burner of EP-A 0 321 809 was inadequate.

[0010] The burner head of EP-A 0 491 079 has a fuel lance with a fuel nozzle. An incoming air conduit is disposed around this fuel nozzle. On the downstream side, the fuel nozzle is closed off with an aperture plate. Disposed around this first incoming air conduit is a further incoming air conduit. This second incoming air conduit is provided, on the downstream side, with a number of guide devices. On the downstream side of the fuel nozzle is a combustion chamber, which in the downstream direction comprises a premixing pipe and an adjoining burnoff pipe whose diameter is larger than that of the premixing pipe. Flame stabilization can be achieved as needed by introducing an interference body downstream of the premixing zone.

[0011] In operation of this burner, some of the incoming air is introduced via at least one aperture plate into a premixing zone located downstream of a fuel nozzle. Another portion of the incoming air, before flowing into the premixing zone, is imparted a swirl by a number of guide devices and is thereafter mixed with a recirculated exhaust gas. Downstream of the premixing zone, at the transition from the premixing pipe to the burnoff pipe, a turbulence ring forms, which surrounds a turbulence return-flow zone that develops at the end of the premixing zone. The initial ignition of the mixture of incoming air and fuel takes place in the turbulence ring.

[0012] In a departure from the mixing of the fuel with a mixture of incoming air and recirculated exhaust gas, European Patent Disclosure EP-A 867 658 describes a method for combusting liquid fuel in which the fuel is first evaporated in recirculated exhaust gas, and only after that is the mixture of fuel and exhaust gas made turbulent with supplied fresh air to which a swirl has been imparted, and ignited. The swirl is attained by providing an annular opening, disposed around the fuel nozzle, in the blocking disk with guide faces that generate a swirl. With the guidance of the air, an underpressure is attained, by which recirculated gases are aspirated into the flame pipe. This combustion is distinguished by previously unattained, extremely low pollutant emissions values. For forming a gasification zone with oxygen-poor hot gas and for flame stabilization, a flame pipe is provided. Upstream, there are recirculation openings on the flame pipe. On the downstream end of the flame pipe, a constriction in the pipe diameter is embodied, which lends stability to the flame.

[0013] A disadvantage of this and other burners is that for stabilizing the flame, a flame pipe is required. Flame pipes are very heavily stressed parts, which are worn down by use in the combustion installation.

[0014] It is therefore an object of the invention to propose a combustion method and a burner head for a low-NOx burner that Allows virtually stoichiometric combustion, which assure that the burner head makes do without a flame pipe yet good stability of the flame is nevertheless achieved, and that the burner head can be used practically regardless of the given conditions of a combustion chamber or boiler chamber and can be adapted to any desired power range.

[0015] This object is attained by the characteristics of independent method claim 1 and by the characteristics of independent apparatus claim 7, respectively.

[0016] In the method for combusting a fuel, fuel and incoming air are delivered to a combustion chamber and ignited in the combustion chamber. The combustion takes place inside a cool and therefore blue flame and with low pollutant emissions values. The incoming air is blown into the combustion chamber in a plurality of divergent incoming air jets that are

spaced apart from one another and that intersect in the chamber. As a result, in the combustion chamber, on the one hand underpressure zones are created between each two incoming air jets, and on the other, a central underpressure zone is also created centrally between the divergent incoming air jets. Oxygen-poor exhaust gases present in the combustion chamber are therefore aspirated from outside into the underpressure zones between the incoming air jets and mix with the incoming air. This delivery of recirculated gases to the flame from outside will hereinafter be called external recirculation. In addition to the external recirculation, oxygen- poor exhaust gases are aspirated axially and counter to the flow direction of the incoming air or of the mixture of incoming air and exhaust gas into the central underpressure zone. This axial delivery will hereinafter be called internal recirculation.

[0017] The incoming air jets intersecting one another in the chamber also intersect a common center axis in the chamber. Because of the inclination of the incoming air jets relative to a plane that includes the common center axis and intersects the incoming air jet, the incoming air jets cause a rotation of the incoming air about the center axis.

[0018] The burner head has a blocking disk, with which an incoming air conduit of a blue-flame burner can be closed off on the downstream end. In the blocking disk, there are at least two openings diametrically opposite one another, and preferably, depending on the burner power, three, four, five, six, seven, or eight openings arranged in a ring. For low power levels, optionally up to 12 openings may be provided. These openings are equipped with guide blades for guiding the air, flowing out of the incoming air conduit through the openings, in the form of incoming air jets that diverge from and intersect each other in the chamber. Between the guide blades, blocking blades are embodied, so as to achieve underpressure zones between the incoming air jets. Downstream of the blocking disk, there is a chamber in which the incoming air jets can spread apart from one another without hindrance. The guide blades and blocking blades preferably form the final air-guiding parts before the flame. As a consequence, a flame is entirely surrounded by exhaust gases present in the combustion chamber. Optionally, a short pip may be provided around the blocking disk, for metering the recirculating exhaust gases along or near the blocking disk.

[0019] With this method and this apparatus, the hydrodynamic and physical-chemical preconditions have successfully been created for stable, practically stoichiometric combustion of heating oil, essentially regardless of the shape and size of the combustion chamber. The combustion produces extremely little pollution, and burners with power levels to suit heating requirements ranging from those of a single-family house to those of entire housing developments or industrial plants are feasible. Since the burner has no flame pipe, it is practically maintenance-free. In a sense, the flame floats at a distance from the blocking disk and the nozzle in the combustion chamber. The flame is cup-shaped and has very soft, frayed contours with innumerable tips that are oriented outward and inward relative to the cuplike shape. The combustion is very quiet and has almost no tendency to pulsation. The sound level values measured in the combustion of heating oil are the quietest of all, compared with those of the most commonly used yellow-flame burners and blue-flame burners.

[0020] A flow axis of each incoming air jet preferably has a minimum spacing from a center axis that is common to all the incoming air jets. The spacing of the axes of the incoming air jets from the center axis is everywhere greater than zero. Thus the flow axes do not intersect the center axis. This creates a swirl effect on the gas flow in the region of the flame. This swirl serves to hold and stabilize the flame.

[0021] The angle between a center axis and the divergent incoming air jets can be adjusted by the angular position of the guide blades and the angular position of the blocking blades. As a function of this angle of the incoming air jets, the cup shape of the flame is more or less widely open. Preferred half-apex angles of a cone, inscribed into the air jets and tangent to them at their entry into the combustion chamber, are between 30° and 45°. However, the flame stability is not threatened even at angles of 20° or 60°. The flow axes of the incoming air jets assume an angle to a jacket line of a cone or cylinder that touches the incoming air jet axis. Since the axes of the incoming air jets do not intersect at a common point of the center axis, the incoming air jets bring about a swirl about the center axis. The incoming air jet axes are theoretically located in a surface of rotation about the center axis that widens in the shape of the bell of a trumpet. In actuality, however, because the cross section of the cup shape of the flame increases with the distance from the blocking disk, an underpressure zone develops in the center of the flame. The effect of this is that the incoming

air jets and the recycled exhaust gases, fanned out between them, form the shape not of the bell of a trumpet, but of a tulip. The incoming air jets are therefore not rectilinear but instead rotated about the center axis; depending on the angle of inclination of the incoming air jet axis relative to the aforementioned conical jacket line, they execute a rotation of from 20° to 120°, and preferably of approximately 90° about the center axis.

[0022] The incoming air jets begin already spaced apart from one another and then diverge. The minimum spacing of the axes of these jets from the center axis may be located upstream of the blocking disk, at the blocking disk, or downstream of the blocking disk. The spacing between the centers of two adjacent incoming air jets in the plane of the blocking disk is advantageously approximately twice the mean diameter of the cross section of the incoming air jets. These conditions can be adjusted by means of the size of the openings in the blocking disk, the size of the blocking blades, or the inclination of the guide blades.

[0023] A departure from the aforementioned ratio is possible to a limited extend. The spacing of the centers may be six times the jet diameter, or 1.5 times the jet diameter. The ratio of the cross-sectional areas of the underpressure zone and air jets can be varied between approximately 1:2 to 5:1. In no case does the ratio of the cross-sectional areas of the underpressure zone and air jets fall below a ratio of 1:3 or exceed a ratio of 8:1. From 70 to 95%, and preferably 80 to 90%, of the incoming air forms the incoming air jets. The rest of the incoming air flows into the combustion chamber, optionally centrally around a central body, such as the fuel nozzle. At high power levels, secondary air making whose volume is 10 to 20% that of the incoming air may be brought to the flame from the outside, through an annular gap in the blocking disk or around the blocking disk. In no case, however, are the incoming air jets disposed around a central incoming air jet.

[0024] If the desired external recirculation is to be achieved, the dimensions of the underpressure zones appear to be significant. For a smaller outermost width of the blocking blades, a greater pressure gradient between the incoming air and the combustion chamber pressure, or a larger cross section of the underpressure zones, is necessary overall, in order to recirculate the same quantity of combustion gas. A preferred outermost width at the outermost base of trapezoidal blocking disks is at minimum 4 to 7 and at maximum 20 to 22 mm, and

especially preferably 12 to 18 mm. A preferred least spacing between round openings in a blocking disk is likewise about 15 mm. A different spacing of openings and blocking blades therefore results, depending on the diameter of a blocking disk or the spacing of diametrically opposite incoming air jets. For larger diameters and higher incoming air pressures, lesser spacings between the incoming air jets are possible.

[0025] A dynamic overpressure of the incoming air, compared to the combustion chamber pressure, of at least 4 to a maximum of 30 mbar, depending on whether the burner has to produce 20 kW or 400 kW, makes it possible to achieve the requisite air quantities and feeding speeds that assure a formation of the underpressure zones that stabilize the flame. At still higher power levels, even higher overpressures must be employed.

[0026] The combustion method according to the invention is suitable for both oil and gas and for dual-fuel burners. Gas is admixed with the incoming air upstream of the blocking disk. Advantageously, liquid fuel is injected axially with a nozzle of full-conical characteristic or conical-jacket characteristic. A nozzle with a mixture of full-conical characteristic and conical- jacket characteristic, in which the fuel is not sprayed as densely in the interior of the cone but is sprayed more densely on the periphery, can also be used. This kind of characteristic is called a mixed characteristic. The conical apex angle of the nozzle is at least 45°, advantageously 60° or more, and at most 90°, and preferably approximately 80°.

[0027] It is even possible, alternatively or in addition to the liquid and/or gaseous fuel, to admix solid fuel particles (such as coal dust) to the incoming air. As a result, the power of the burner can be increased. The key component of the combustion method is the burner head with integrated incoming air guidance, where the burner head is not adjoined downstream by any flame pipe that would hinder the lateral propagation of the incoming air jets or the external recirculation.

[0028] The mixing temperature of the incoming air, exhaust gas and fuel vapor must, in a first phase until the complete evaporation of the fuel, remain below the ignition temperature of this mixture; that is, the recirculation quantity must not be too high. An overly small recirculation quantity, conversely, would mean inadequate evaporation and therefore

suboptimal combustion and relatively high pollutant values. Not until the three components have formed a homogeneous gas mixture should the ignition be initiated, with a second recirculation of gases that are as hot as possible.

[0029] With the aforementioned first recirculation of not excessively hot exhaust gases, the thermal energy required for evaporation is furnished. The admixing of this exhaust gas lowers the oxygen content of the mixture and requires a flow distance that creates a spacing between the root of the flame and the blocking disk. The mixture ratio determines the gasification and combustion temperature. The impetus generated by the air guidance and the injected fuel generates suction and least to a first external recirculation of hot combustion gases. This flow of hot gas is aspirated inward between the incoming air jets. The first hot-gas recirculation flow, together with the incoming air, consequently forms an annular flow that propagates in cup-shaped fashion and rotates about its center axis. The spreading apart of the laminar, turbulent shear flow of the delivered incoming air into the combustion chamber and the hot gases fanned out between the incoming air jets creates a further underpressure zone in the center axis, which causes the internal hot-gas recirculation. Liquid fuel is injected into the hot gases of the internal recirculation and into the cup-shaped flow. The hot gases of the internal recirculation gradually mix with the cup-shaped flow. The cup-shaped flow comprises an increasingly flammable mixture that comes into contact on all sides with hot combustion gases and mixes with them. Because of this mixing, the temperature of the mixture rises to above the ignition temperature. The flame therefore burns, with innumerable tongues of flame to all sides, inward and outward, in countercurrent to a second hot-gas recirculation. The combustion takes place with a blue, low-NOx hollow-conical flame and with NOx values that are at the limit of what is theoretically feasible, and moreover with a low level of sound.

[0030] A further advantage of the burner and the method is that the burner and the method can be employed with natural gas as the fuel. The gas may be admixed with the incoming air in the region of the blocking disk, in the incoming air conduit between the fan and the blocking disk, or on the intake side of the fan. With gas as the fuel, the evaporation of the fuel is eliminated. Mixing in hot recirculated gases raises the temperature of the mixture while simultaneously reducing the oxygen concentration. A decisive aspect here is the

attainment of a completely homogeneous mixture in the mixing zone, before the combustion is brought to ignition by the second hot-gas recirculation at a distance from the blocking disk.

[0031] The burners for oil and gas can be combined in a dual-fuel burner. There is also the possibility of a further combination of a fuel, such as coal dust, in high-power combustion installations.

[0032] The stable internal flow conditions result in a very calm, non-flickering flame, which decisively lessens both noise emissions and the inducement of pressure pulsations in the chimney.

[0033] A burner head for disposition on the end of an incoming air conduit of a blue-flame burner has a blocking disk that closes off the incoming air conduit on the downstream end. In the blocking disk, there are a plurality of spaced-apart openings arranged in a ring. These openings serve to split up a majority of the incoming air, advantageously over 70% of it, into incoming air jets. Guide blades are provided at the openings. These blades serve to guide each incoming air jet flowing out of the incoming air conduit through an opening. They guide the incoming air jet in a direction that diverges from the direction of the other incoming air jets. Between the guide blades, blocking blades are embodied. With the blocking blades, underpressure zone are achieved between the incoming air jets. To enable the gas flow, in which the flame develops, to develop unimpeded, the guide blades and the blocking blades are advantageously the last flow- carrying parts, in terms of the flow direction, before the flame.

[0034] The blocking blades and the guide blades are advantageously embodied integrally with the blocking disk. The blocking blades are advantageously embodied as trapezoidal. As a result, the blocking blades, the guide blades, and the entire blocking disk can be cut and shaped from a single piece of sheet metal. This makes the production of the blocking disk very simple. Advantageously, the guide blades adjoin the blocking blades along one edge, in particular a bending edge, and at this edge the guide blades (23) and blocking blades (27) form an angle of between 100° and 160°, preferably between 110° and 140°.

[0035] The openings are advantageously embodied around a central body. In the case of an oil burner or a dual-fuel burner, the central body is the oil nozzle. In a gas burner, the central body has no further function. The central body helps to create a central underpressure zone and already guides the air even in the incoming air conduit. The guide blades accompany the sip in the flow direction of the incoming air. The edge of a given guide blade accompanying the central body forms an angle with a jacket line of the central body.

[0036] Advantageously, however, the guide blade does not rest completely on the central body, so that a fine annular gap exists around the fuel nozzle. This gap allows a light quantity of incoming air to be delivered to the fuel stream through the annular gap, which is advantageous in terms of the performance of the burner during starting.

[0037] A blue-flame burner having an incoming air fan, an adjoining incoming air conduit, a fuel delivery means, and an electric ignition is equipped with a burner head. Such a burner has the advantages that are specific to this burner head. The incoming air fan is dimensioned to suit the burner power. The fuel delivery may be assured by a gas delivery means upstream of the blocking disk, and/or by an oil nozzle in the center of the blocking disk.

[0038] Such a burner is expediently built into a boiler. The boiler has a boiler chamber which is advantageously subdivided by a heat exchanger into a central combustion chamber and an exhaust gas chamber encasing the combustion chamber parallel to the inflow direction of the incoming air. Advantageously, the heat exchanger is a gap coil heat exchanger. With gap coil heat exchangers, a high yield of convection heat is attained. Such a gap coil heat exchanger is therefore especially well suited to blue-burning flames, which radiate little heat.

[0039] The advantages of the method and the burner head are especially these:

- their low production costs,
  - since a flame cup or flame pipe and in general wearing parts of any kind toward the combustion chamber, such as built-in interference-body fixtures, etc., are eliminated, and

- thanks to very simple construction for the air guide;
- their great ease of serving,
  - thanks to the preclusion of soiling of the burner head,
  - thanks to which there are no wearing parts in the combustion chamber; and
- their extremely low pollution values:

  NOx with oil, ca. 40 mg/kWh

  NOx with gas, ca. 20 mg/kWh.

[0040] The invention is described in further detail below in terms of exemplary embodiments, in conjunction with the drawings. Shown are:

[0041] Fig. 1, a longitudinal section through a yellow-flame burner of the prior art;

[0042] Fig. 2, a view of the air pattern in such a yellow-flame burner;

[0043] Fig. 3, a longitudinal section through a burner head according to the invention in a burner pipe, without a flame cup that meters the first recirculation;

[0044] Fig. 4, a longitudinal section through a burner head according to the invention in a burner pipe, with a flame cup that meters the first recirculation;

[0045] Fig. 5, a perspective view of an aperture plate with four openings and with a fuel nozzle placed between them;

[0046] Fig. 6, a perspective view of an aperture plate with four openings and with a fuel nozzle placed between them, and with schematically shown incoming air jets;

[0047] Fig. 7, a longitudinal section through a burner head in a burner pipe, with an aperture plate with five circular openings;

[0048] Fig. 8, a front view of the burner head of Fig. 7;

[0049] Fig. 9, and aperture plate with six trapezoidal openings and six trapezoidal blocking blades between them;

[0050] Fig. 10, a cross section through the aperture plate of Fig. 9, in which the blocking blades are located in a single plane;

[0051] Fig. 11, a cross section through the aperture plate of Fig. 9, in which the blocking blades are bent upward in the shape of pyramid;

[0052] Fig. 12, a longitudinal section through a burner head of a gas burner, schematically showing the flows of fresh air and hot exhaust gases;

[0053] Fig. 13, a longitudinal section through a burner head of an oil burner, schematically showing the flows of fresh air and hot exhaust gases;

[0054] Fig. 14, a longitudinal section through a boiler and a burner with a burner head of Fig. 13;

[0055] Fig. 15, a longitudinal section through a short boiler with a coiled gap heat exchanger and a burner with a burner head adapted to the given spatial conditions.

[0056] Elements that are approximately equivalent to one another in function are identified in the drawings by the same reference numerals, even if they differ in shape.

[0057] In Figs. 1 and 2, a longitudinal section through a yellow- flame burner 10 and a view of the flows in the region of the flame of such a yellow-flame burner 10 are shown. The blocking disk 17 of the yellow-flame burner 10 of Fig. 1 differs in shape from the blocking disk 17 shown in Fig. 2. Nevertheless, the flow pattern for a burner 10 as shown in Fig. 1 is very similar to the flow pattern shown in Fig. 2.

[0058] In the yellow-flame burner 10 of Fig. 1, a burner pipe 13 and a blocking disk 18 that closes off the burner pipe 13 on the downstream end, upstream of combustion chamber 15, are shown in section. An oil nozzle 19 and two ignition electrodes 21 (only one of them is shown) are disposed in the burner pipe 13. The blocking disk 17 has a central opening 20, and around this opening is a blocking ring 22 with eight guide blades 23, and around this blocking ring 22 is an annular opening 26. Large blocking blades 27 are disposed between the guide blades 23 and together with an outer region of the blocking ring 22 they create an annular underpressure zone 28 (Fig. 2). In the center of the annular underpressure zone 28, the primary proportion of the incoming air flows in the form of a sharply pointed incoming air jet 30 into the combustion chamber 15. An incoming air jacket flows around the underpressure zone 28 into the combustion chamber 14. Because of the pressure differences and the differences in the flow speed of the incoming air, there are resultant recirculation flows 34 at the inner edge of the underpressure zone 28. A slight quantity of incoming air flows into the underpressure zone through the small slit openings 36 between the guide blades and the blocking blades and causes a rotation of the gases in the underpressure zone 28 around the central incoming air jet 30. The fuel is injected into the incoming air jet 30 and partly made turbulent by the recirculation flows 34 in the underpressure zone. In the underpressure zone, the fuel burns under conditions of oxygen deficiency. These flow and pressure conditions keep the flame at the blocking disk. No further provisions are therefore necessary to obtain a stable flame. However, such a burner burns with a yellow flame, and at high combustion temperatures and with high pollutant emissions values.

[0059] With the invention, success has now been achieved in creating pressure and flow conditions in a blue-flame burner 11 that keep a stable, quiet, blue-burning flame floating in the combustion chamber 15.

[0060] In the longitudinal sections through two burner pipes in Figs. 3 and 4, no oil nozzles 19 are shown. However, the location of the oil nozzle 19 can be seen in later figures. The burner pipe 13 of Figs. 3 and 4 forms an incoming air conduit for fresh air and if need be natural gas. On the axis 31, which can be called the axis of symmetry or the flame axis, the oil nozzle is located with its nozzle opening approximately in the plane of the blocking disk 17.

[0061] The burner pipe 13 is closed off on the downstream end by a blocking disk 17. The blocking disk 17 is composed of a retaining ring 35 with a central opening and an aperture plate 37 that covers the central opening of the retaining ring 35. The retaining ring is hammered onto a sealing ring 39 on the downstream end of the burner pipe 13, in terms of the flow direction of the incoming air. On the retaining ring 35, there are two ignition electrodes 21 (in Figs. 3 and 4, only one is shown) and a mount 41 for the fuel nozzle 19 (not shown). The mount 41 is not shown in section. A pipe 43 for flame monitoring is also mounted on the retaining ring 35.

[0062] The aperture plate 37 is hammered onto the retaining ring in the flow direction and firmly screwed to it. The aperture plate 37 is an approximately circular disk with a central opening for the tip of the fuel nozzle 19 (see Fig. 5). In a ring around the central opening, the sheet metal from which the aperture plate 37 is made is cut to size and shape with a laser. In the process, twelve laminations are cut out, which can be bent over to form guide blades 23. Half of the guide blades 23 are visible in each of Figs. 3 and 4. These guide blades 23 are each located at the edge of an opening 45. The openings 45, alternating with blocking blades 27 disposed between the openings 45, form a ring around the fuel nozzle. The guide blades 23 are joined to the blocking blades 27 via approximately radially extending bending edges 47. The guide blades 27 are cut to size and shape such that in the bent-over state of the guide blades, an inner edge of the blade extends approximately parallel to an outer shape of the fuel nozzle 19. The inclination of the guide blades to the blocking blades is approximately 45°, in the examples shown in Figs. 3-6. The blocking blades 27 are located in a common plane.

[0063] In Fig. 4, the same arrangement as in Fig. 3 is shown, but with one difference: In Fig. 4, there is additionally a short flame pipe, for metering the quantity of recirculated hot gas. This flame pipe 49 has the same diameter as the burner pipe 13. It is manufactured in one piece with the burner pipe 13. Between the flame pipe 49 and the burner pipe 13, an annular gap 41 is embodied. This annular gap meters the recirculation of the exhaust gases. A flame pipe of this kind may be provided in the burner according to the invention. However, it is not necessary. In practically any combustion chamber 15 and at any power level, stabilization of the blue flame can be achieved even without a flame pipe 49, by means of the choice of

aperture plate and its adjustment.

[0064] The aperture plate 37 in Fig. 5 has four openings 45 around the central opening. Four blocking blades 27 are disposed between these openings 45. The blocking blades 27 are trapezoidal. The base of the trapezoid is located on an outer arc. The two converging sides of the trapezoid extend approximately radially. The openings have practically the same cross section as the blocking blades 27. The guide blades 23 do have a larger surface area than the blocking blades 27, but the opening 45 is smaller than the area of the guide blades 23, since the guide blades 23 are not perpendicular to the plane of the aperture plate. The bending edge 47 between the blocking blades 27 and guide blades 23 forms one of the converging sides of the trapezoid. The other side of the trapezoid of the blocking blades 27 is formed by a cutting edge. This cutting edge and the bending edge 47 are more convergent relative to the blocking blades 27 than relative to the opening 45 between two blocking blades 27.

[0065] In Fig. 6, the aperture plate shown in Fig. 5 is shown at a shallower angle of view and is provided with schematically shown incoming air jets. The aperture plate 37 has four openings 45, from which incoming air flow out during operation of the burner. The incoming air is split up by the blocking blades 27 and the guide blades 23, as well as the fuel nozzle 19 (or some other central body), into four incoming air jets 53. These incoming air jets 53 are shown here as transparent bodies. The enter through the openings 45 in the aperture plate 37 at an angle of other than 90° to the plane of the aperture plate 37 and of the blocking disk 17. In the process, the incoming air jets 53 force gases located downstream of the blocking blades 27 to be entrained with them. The resultant underpressure aspirates gases from the surroundings, so that a slower gas flow develops between each two incoming air jets 53. These gas flows are essentially formed by hot gases, which are exhaust gases from combustion and therefore poor in oxygen. Between the laminar flows of incoming air and hot gases, mixed zones occur. In these mixed zones, incoming air and exhaust gases are mixed with one another. The incoming air flowing into the underpressure zones from the incoming air jets 53 become turbulent from the hot gases. As a result, the incoming air jets 53 are consumed. They are therefore shown in the form of arms, each ending in a tip. Since the incoming air jets 53 diverge, not only a peripheral underpressure zone 55 between each two incoming air jets, but also a central underpressure zone 57 between the incoming air jets 53

on the axis 31 are created. These underpressure zones 55, 57 prevent the incoming air jets 53 from propagating in a straight line. The underpressure zones keep these incoming air jets 53 together and therefore cause the flame to burn in a tuliplike shape.

[0066] The liquid fuel is injected into the turbulent gas flows. It does not matter that the oil droplets get into not only the hot gases but also the incoming air flows. In both cases, the gasification and evaporation (depending on the temperature of the ambient gases) occur before the ignition of the fuel. The flame therefore burns blue. It is suspected that the gas temperature within the incoming air jets, and the oxygen and fuel concentrations in the hot gases, are not high enough until the fuel is already in the gaseous state. The temperature of the gases increases with the distance from the blocking disk 17, because of the inflow of hot gases in a secondary recirculation. The secondary recirculation takes place both from the inside and from the outside toward the cup shape of the flame.

[0067] Because of the pressure conditions that arise with the peripheral underpressure zones on the one hand, which are built up by the expelled incoming air and shrink toward the blocking disk 17, and the central underpressure zone on the other, which is generated by the flowing apart of the incoming air jets and the hot gases entrained with them, an equilibrium of the underpressure zones develops. In this state of equilibrium, turbulence is brought about, which predominates over the dynamics of the highly thermodynamic process and lends stability to the flame. The thermodynamic process proceeds primarily not from back to front in the outflow direction, but from the flame interior in the direction of the tip of the flame. The top of the flame, however, is long located on a flame axis. Instead, there are innumerable tips of flame on the inside and the outside of the cup-shaped flame. Because of this, it must be suspected, the influence of the thermodynamic process on the stability of the flame is partly canceled out, so that the dynamics of the flows suffices to hold the flame securely.

[0068] It must therefore be assumed that the shape of the openings plays a subordinate role. Thus in Figs. 7 and 8, a burner head is shown in which five openings, each of them circular, are stamped out of the aperture plate 37. The stamping encompasses an arc of approximately 300°. Over an angle of 60° there is a bending edge 47, along which the guide blade 23 is joined to the aperture plate 37. The direction of the incoming air jets entering

through these openings 45 must, because of the guide blades 23, be at an angle to the axes (not shown) of the openings in the aperture plate 37. The incoming air jets are furthermore oriented at a tangent to a circular cylinder containing the axes of the openings, and the place where the incoming air jets have the least spacing from the axis 31 is therefore located in the plane of the aperture plate 37.

[0069] In Figs. 9-12, two aperture plates 37 are shown, which have six openings 45. The aperture plates are formed from one piece of sheet metal, on the order of the aperture plates shown in Figs. 3-6. The guide blades 23 are joined to the blocking blades 27 via a bending edge 47. In Figs. 9 and 10, the six blocking blades 27 are shown flat and disposed in the same plane. In Fig. 11, however, the blocking blades 27 are bend upward in the flow direction of the incoming air. As a result, the resultant incoming air jets are inclined outward. Because of the angling of the blocking blades 27, the primary recirculation of the hot gases along the blocking disk 17 is effected with less turbulence to a greater depth between the incoming air jets.

[0070] The guide blades 23 are bent counter to the flow direction of the incoming air. The result is tearing edges, at which the incoming air flow detaches and an underpressure develops. A nozzle opening is provided centrally in the aperture plate 37. It is advantageously made so large that there is a fine air gap all the way around the nozzle.

[0071] In Figs. 12 and 13, the flow pattern and the flame pattern of the gas flame and the oil flame are shown. The two flow patterns are identical. Only the fuel delivery is different. In Fig. 12, the fuel delivery means is formed by a gas nozzle 18 in the plane of the blocking disk 17. The gas outlet openings are oriented at an angle of 45° to the axis 31. The gas therefore enters into the incoming air flowing past the gas nozzle 18 and enters the flame along with the incoming air jets 53. However, gas may also be delivered to the incoming air upstream of the blocking disk.

[0072] In contrast to this, oil is injected directly into the combustion chamber 15. The oil first reaches the region of the central underpressure zone 57. In the hot gases in the central underpressure zone 57, a large proportion of the fuel evaporates in an oxygen-poor

environment. A subordinate proportion of the fuel, in droplet form, penetrates the hot gases in the peripheral underpressure zones 55 and is suspected also to penetrate the incoming aïr in the incoming air jets 53. Despite the fact that it must be suspected that oil droplets get into the incoming air jets 53, no yellow flame is produced. The flame burns extremely calmly and stably and with an extremely blue color. It must be assumed that the oil droplets entering the incoming air jets have already been heated and therefore evaporate very quickly in the incoming air jets, that the temperature of the incoming air in this region is below the ignition temperature, and that the proportion of fuel entering the incoming air jets that has not yet been gasified is only slight.

[0073] As can be seen from Figs. 12 and 13, the incoming air 61 from the incoming air conduit or burner pipe 13 arrives through the openings 45 in the aperture plate 37 in the form of incoming air jets 53 that enter the combustion chamber 15. The incoming air jets 53 are oriented, thanks to the guide blades 23. Between the incoming air jets 53, the blocking blades 27 between the openings 45 create peripheral underpressure zones 55 in which it is primarily hot gases from outside that are recirculating. The incoming air jets 53 and these primarily recirculating hot gases 63 in the peripheral underpressure zones 55 form a laminar, turbulent shear flow and mix with one another and form a cup- shaped, rotating jacket flow 65 with a central contrary flow 67 of oxygen-poor hot gases. Because the cup-shaped jacket flow 67 is made turbulent by the secondarily recirculating hot gases 67, 69 from the central underpressure zone 57 and the periphery, a homogeneous mixing of hot gases, incoming air and fuel gases occurs, making very harmonious combustion possible.

[0074] The expansion of the gases that occurs in the flame can expand toward the axis 31 and outward. The dynamics resulting from the thermal development therefore lose tension predominantly annularly and radially toward the inside and outside. The incident forces are thus to a great extent oriented counter to one another. As a result, in terms of stabilizing the flame, the dynamics that are axially losing tension between the incoming air jets 53 and the underpressure zones 44, 47 remain dominant over the thermodynamic processes that are developing radially.

[0075] In Fig. 14, the burner head of Fig. 13 is used in a conventional boiler. The

burner is equipped with a fan, an oil pump, and an electronic ignition. The dynamics of the flows that is attained by means of the blown-in incoming air in the combustion chamber 15 of the boiler are not addressed in this description. This is because the shape and side of the combustion chamber 15 has to meet only a single condition: The combustion chamber must offer room for the flame to develop. Certainly pressure conditions and other parameters of the combustion chamber and boiler do influence the behavior of the flame and the combustion. However, so far no boiler has been found in which stable, low-polluting combustion of oil or gas with the burner head described would not be successful. The flame even burns in the open and under spatially very tight conditions.

[0076] The boiler of Fig. 14 is designed for a lance-shaped flame and therefor offers too much room in the direction of the axis 31. Nevertheless, the combustion proceeds very cleanly, calmly and stably. The exhaust gases are turned around and delivered to the chimney through a heat exchanger.

[0077] In Fig. 15, a very short boiler is shown. A flame deflector 71 is located diametrically opposite the burner head. Until now, the short dimensions of the combustion chamber 15 were achieved by deflecting the flame back to its root with the flame deflector 71. However, with the composition of the boiler shown, this flame deflector 71 is no longer required. It merely has to divide the combustion chamber 15 from a flue-gas chamber 73 downstream of the flame deflector 71. The flame formed by the method of the invention burns radially in a cuplike shape and has a very short lengthwise development. It is therefore suitable even for very short combustion chambers 15.

[0078] In the boiler shown in Fig. 15, which is a wall-mounted unit, a gap coil heat exchanger 75 is provided, which cylindrically encases the combustion chamber 15. Between the gap coil heat exchanger 75 and the wall of the boiler, a cylindrical- jacket-shaped exhaust gas chamber 77 is formed. This exhaust gas chamber is separated from the flue-gas chamber 73 by the first several windings of the gap coil heat exchanger. The flue-gas chamber 73 has an opening in a flue 79. The flue 79 has a plastic pipe with an integrated fresh-air conduit 81.

[0079] The fresh air is aspirated through the fresh-air conduit 81 in countercurrent to

the flue gas in the flue 79. With the fan 83, the incoming air is guided through a very short burner pipe 13 to against the blocking disk 17. With the aperture plate 37 in the blocking disk, incoming air jets 53 are formed, which flow into the combustion chamber 15. In the lee of the blocking blades 27 of the aperture plate 37, peripheral underpressure zones form between the incoming air jets 53 and a central underpressure zone 57 forms in the center. The injected heating oil vaporizes/evaporates in secondarily recirculated hot gases in the central underpressure zone 57 and together with these hot gases is mixed into the tulip-shaped jacket flow 65 made up of incoming air and primarily recirculated hot gases and is burned in a blue flame. The resultant hot gases are partly recirculated and escape from the combustion chamber 15 into the exhaust gas chamber 77 between the gap coils of the heat exchanger 75. In the process, they give up a majority of their thermal energy to the heat exchanger by convection. These already cooled exhaust gases pass through the gap coil heat exchanger 75 a second time and enter the flue-gas chamber 73. Since the supply line for the medium flowing in the heat exchanger is provided in the region of the flue-gas chamber 73 and the diversion of the medium is provided in the region of the burner head, the exhaust gases flow first through a hotter region of the heat exchanger and in the second pass through it flow through a cooler region. After that, the cooled flue gases enter the flue and cool down the aspirated fresh air before they escape into the atmosphere.

[0080] In the following table, parameters for seven examples of aperture plates of burner heads of the invention are listed. The aperture plates are embodied on the order of the aperture plate of Fig. 5. The burner heads are designed for power levels of 16 to 700 kW. The rings of openings in the aperture plates have an outer diameter of 27 to 80 mm and therefore a circumference of 84.8 to 251.2 mm.

[0081] In experiments burners for high power levels, it has been demonstrated that a smaller number of openings and blocking blades is preferable to a larger number. The number of four openings and for blocking blades has proved suitable for all power levels. A division by four has therefore been used for all the examples. The dimensions of the blocking blades and of the openings between the blocking blades are arrived at as follows. The terms are given in Fig. 5. The length of the shorter side of the trapezoid of the blocking blades, which adjoins the fuel nozzle, is marked A. C is the width of the base of the trapezoid of the

blocking blades. H is the greatest width between two adjacent blocking blades 27. This is the spacing of the bending edge and the cutting edge, diametrically opposite it relative to the opening, at their points of intersection with the circumferential circle of the ring of openings. H/C represents the ratio of the dimensions H and C on the circumferential circle. This ratio is approximately equivalent to the ratio of the cross-sectional areas of incoming air jets and underpressure zones. This ratio varies approximately inversely proportionately to the dynamic pressure P of the incoming air. The rated values for the fans are indicated in millibars in column P. Despite major differences in terms of power (1:45), the ratio of C to H (1:5), and the dynamic pressure of the incoming air (1:4), the product of P(mbar) and C/H for the burners is within relatively narrow limits between 7.3 and 11.7 (1:1.6).

POWER (kW)	Ø DIAMETER	PITCH	A	C	H	CURCUMFERENCE	H/C	P(mbar)	$\frac{P*C}{H}$
16	27	4	2	12	9	84.8	1:1.3	9	11.7
22	30	4	2	13	10.5	94.2	1:1.24	7.5	9.3
28	35	4	2	14	13.5	109.9	1:1.04	7.5	7.8
45	40	4	2	16	15.4	125.6	1:1.04	9	9.4
70	45	4	2	18	17.3	141.3	1:1.04	10.5	10.9
250	60	4	2	15	32.1	188.4	1:0.47	17	8
700	80	4	2	13	49.5	251.2	1:0.26	18	7.3

[0082] In summary, a burner head in an aperture plate 37 has at least two and preferably four openings 45 in an aperture plate 37, with uniformly inclined guide blades 23 for the delivery of incoming air to a combustion chamber 15 in the form of incoming air jets 53. Between the openings 45, blocking blades 27 are embodied, for forming peripheral underpressure zones 55 between the incoming air jets 53. The incoming air jets 53 are deflected by the guide blades 23 into a position that is inclined relative to a common center axis 31. The incoming air jets 53 therefore diverge and as a result create a central underpressure zone 57 about the axis 31 between the incoming air jets 53. By means of the central underpressure zone and the inclination of the incoming air jets relative to the center axis, a rotation of the incoming air about the center axis 31 is achieved. In operation of the

burner, hot gases from outside are aspirated into the peripheral underpressure zones 55 and, counter to the flow direction of the incoming air, into the central underpressure zone 57 between the incoming air jets 53. These flow conditions create ideal conditions for the combustion of gaseous, liquid and/or particulate fuel in a calm, cool, low-polluting flame. This combustion is practically independent of the size and shape of the combustion chamber and of the pressure conditions in the combustion chamber. This combustion method and such apparatuses are suitable for combustion installations of 16 kW to 1000 kW, or more.